

A Current View on Strawberry Production Practices and Trends in the Northeastern United States and Canada

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ABSTRACT. Strawberries (*Fragaria xananassa*) are an important crop for diversified fruit and vegetable farms in the northeastern United States as well as in Ontario and Québec, Canada. The industry in this cold climate region differs greatly from that in the major strawberry-producing states of Florida and California because strawberries typically represent a smaller share of total farm revenue and are sold primarily through retail markets. In recent years, strawberry production and marketing methods in the northeastern United States and Canada have diversified to meet the unique challenges of the region, including regional demand, extended seasons, and management of an increasingly challenging pest and disease complex. In 2020, we distributed an online survey to 163 commercial producers to obtain a snapshot of marketing and production practices used on strawberry-producing farms in this region and to assess research and outreach needs to better serve the industry. We conducted in-depth case study interviews with a small number of producers after the survey. We found that traditional June-bearing strawberry production continues to represent >50% of production, and that most fruit are grown conventionally. Day-neutral strawberry production was reported by an increased number of producers in New York as well as in Canada, and a higher percentage of day-neutral growers, compared to that of June-bearing producers, reported using protected culture. *Botrytis* (gray mold), weeds, and leaf spots were the top overall pest pressures indicated by growers. Survey respondents preferred written outreach materials and on-farm meetings to obtain information. Integrated pest management, organic production, and cultivar performance were the top priorities for subjects. The survey and interviews also provided information about the most common strategies for winter protection, frequency of pesticide applications, lifespan of plantings, and other current strawberry production practices in the region. Our survey results may be used by researchers and extension professionals to better serve this diversifying industry.

Strawberries (*Fragaria xananassa*) are produced on 2400 farms and more than 3600 acres in the northeastern United States (US) (US Department of Agriculture, National Agriculture Statistics Service 2019); in adjacent eastern Canada, Québec and Ontario lead the country in strawberry cultivation, with more than 8000 acres in production (Statistics Canada 2021). In the northeastern US, commercial strawberry production peaked in the 1970s and 1980s, and it has declined since that time as production in California and Florida and imports increased (Harbut et al. 2016; Samtani et al. 2019; Tourte et al. 2016; Wu et al. 2012); however, the crop remains important for regional producers. Strawberries are the first fruit

to ripen in the spring, thus signaling the start of the growing season and drawing customers to farms. Unlike the main strawberry production regions of the US, which primarily grow for wholesale markets, the majority of northeastern crops are marketed directly to consumers, and most fruit are consumed within the region (Samtani et al. 2019). Thus, the crop is important for agritourism and local food marketing efforts.

The season for fresh strawberries is short in the north and is typically 1 month for June-bearing cultivars (Orde and Sideman 2023; Samtani et al. 2019). Challenges that limit strawberry production success include labor access and costs, competitive regionally adapted cultivars, access to planting stock, weed management, pests and diseases, winter

protection, managing spring frosts, and crop rotation limitations (Bandara 2021; Hernández-Martínez et al. 2023). These challenges have resulted in the proliferation of diverse production strategies on farms to improve product quality, enhance marketing efforts, extend the season, and improve profitability of the strawberry enterprise.

There is no single strawberry production system in the Northeast. June-bearing cultivars are frequently grown in the traditional perennial matted-row system, but some growers use plastic mulch to improve weed management and yields, and day-neutral cultivars are also grown to extend the fruiting season. The perennial matted-row system uses straw mulch, and runners are allowed to root between plants. This system has remained popular in the northeastern US and other cold-climate regions, such as Poland and Scandinavia (Black et al. 2002; Bornt et al. 1998, Hancock and Simpson 1995); however, weed control is difficult in matted-row systems (Bornt et al. 1998), particularly in organic systems. In recent decades, strawberry production in the US has moved toward the “annual hill” or annual plasticulture production system, thus drawing increased researcher interest (Black et al. 2002; Hancock and Simpson 1995; Samtani et al. 2019; Voth and Bringham 1990; Weber 2021a, 2021b). This system uses raised beds, plastic mulch, and drip irrigation, and runners are removed (Hoffman et al. 2024; Orde and Sideman 2023; Voth and Bringham 1990). Plasticulture systems are typically kept for only one fruiting season.

The initial costs associated with plasticulture systems are greater than those for matted-row systems, but they are often offset by higher yields, earlier and larger fruit, more efficient harvesting, and added control over irrigation and fertility applications (Black et al. 2002; Bornt et al. 1998; Hoffman et al. 2024; Fiola 1998; Orde and Sideman 2023; Poling and Safley 1986). Increased labor costs associated with matted-row systems are also reduced. Although matted-row systems are typically covered in straw for winter protection, less expensive reusable row cover is often used in plasticulture (Orde and Sideman 2023). The degree to which the industry has adopted plasticulture systems and that to which it is moving away from traditional

matted-row June-bearing strawberry production have not been documented.

Modified environments (i.e., low tunnels, caterpillar tunnels, high tunnels, or hoophouses) can result in increased yields, decreased disease pressure, improved fruit quality, and an extended season for strawberry (Conner and Demchak 2018; Demchak 2009; Kadir et al. 2006). During a recent study in New Hampshire, the season-long percent marketable yield for day-neutral plants was 8% to 11% greater under low tunnels than that of traditional open beds (Orde and Sideman 2019). Producing fresh fruit outside the normal June-bearing harvest season presents the opportunity for producers to charge premium pricing because consumers are increasingly demanding quality local produce year-round.

An important motivation for growers to explore a variety of production practices is the formidable pest and disease complex of strawberries. Growers recognize that many consumers, although they favor locally grown strawberries, would also prefer organic practices and minimal pesticide usage (Samtani et al. 2019).

Strawberries are short in stature with shallow root systems and do not compete well with weeds. Grain and weed seeds brought in on poor-quality straw often become problems in northeastern strawberry fields that overwinter berry plants with mulch (Orde and Sideman 2023). Diseases of strawberries also present production challenges. Soil-borne diseases including *Verticillium*, *Phytophthora*, *Fusarium*, and *Rhizoctonia* are the reasons for long (5–7 years) rotations out of strawberry and related plant families (Koike and Gordon 2015; LaMondia 2004; Muramoto et al. 2014). Crown and fruit anthracnose (*Colletotrichum* sp.) has become a major problem in both day-neutral and June-bearing strawberry fields (Poling 2008; Smith 2008). Insect and mite pests, including tarnished plant bug/Lygus bug (*Lygus lineolaris*), two-spotted spider mite (*Tetranychus urticae*), strawberry sap beetle (*Stelidota geminata*), and strawberry clipper (*Anthrenus signatus*), have been the predominant insect pests for decades (Lahiri et al. 2022; Orde and Sideman 2023). The development of scouting techniques, action thresholds, and the availability of biological controls have helped growers manage these pests, but grower time and expertise are required to use these tools to their best effect. Spotted wing drosophila (*Drosophila suzukii*) use day-neutral strawberries as hosts in the northeastern US and Canada, whereas June-bearing cultivars usually avoid infestation (Loeb and Carroll 2012; Ontario Ministry of Agriculture, Food and Rural Affairs 2022; Schloemann et al. 2020). Wildlife may account for more loss than that associated with all other pest categories combined. White-tailed deer (*Odocoileus virginianus*) pressure in the Northeast is enormous (Paulin et al. 2022) because they browse plants during increasingly snowless winters, which may be an important factor associated with poor winter survival of plants. Avian damage is increasing during our warmer and drier growing seasons, and many small growers are using bird netting routinely. Slug (Gastropoda: Pulmonata) damage remains a challenge during wet years (Caldwell and Pritts 2001). Ultimately, pest management has become an increasing challenge in a changing climate with more extreme weather events and the arrival of invasive species.

Regardless of the growing system, access to accurate information is necessary to increase strawberry profitability, reduce environmental impacts, manage pests successfully, and adapt to production in a changing climate, as well as to compete with other strawberry-producing regions. Information about tradeoffs and the performance of different production systems and technologies, including protective structures such as tunnels, is limited. Innovative and specialized systems that combine features of multiple production systems are commonplace, and many options are available to prospective strawberry growers. Growers' perceptions and their stated needs for information, research, and outreach have not been documented.

We present the results of a 2020 grower survey and series of interviews that aimed to describe the strawberry industry and document grower needs in the northeastern US as well as in Ontario and Québec, Canada. Throughout, we refer to the “northeastern US” or “Northeast” as defined by the US Census, including Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and Rhode Island (collectively referred to as New England), New York, New Jersey, and Pennsylvania (US Department of Agriculture, National Agriculture Statistics Service 2019). The specific objectives of the study were as follows: estimate the proportion of revenue attributable to strawberry sales on individual farms; identify strawberry production systems and practices used; characterize marketing channels for strawberries; identify production challenges that limit strawberry yield; and assess the needs for future research, educational outreach programs, and technical resources required to advance strawberry production in the Northeast and eastern Canada. Our results may serve as a needs assessment for applied research and extension programming efforts to support this industry.

Methods

GROWER SURVEY. A survey instrument using the Qualtrics online platform (Provo, UT, USA) was developed with the objective of identifying extension and research needs and current production practices used by growers throughout the northeastern US and eastern Canada (Supplementary

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Material 1). The survey received internal review board approval (IRB-FY2021-43) and was distributed in English and French to an estimated 2500 individuals throughout the region (Sideman et al. 2020). We relied on existing extension networks and received assistance from colleagues in all New England states, New York, and Pennsylvania, as well as in Ontario and Québec, Canada, to distribute the survey electronically. Questions sought information about the farm operation, marketing strategies, challenges experienced during strawberry production, and pest management strategies. Additional questions covered cultivar selection, planting dates, and yield. Respondents were also asked to provide details about the types of strawberry (June-bearing and day-neutral) that they grow.

Between 1 Dec 2020 and 3 Feb 2021, 170 complete responses were received; however, a total of 269 respondents began the survey. Ultimately, 163 respondents consented to participate in the survey, and data from their responses were subjected to analysis. All 163 respondents currently grow strawberry fruit for sale. Responses were grouped by region for comparison (Fig. 1). During this study, southern New England comprised Connecticut, Massachusetts, and Rhode Island, northern New England comprised

Maine, New Hampshire, and Vermont, the mid-Atlantic comprised Delaware, Maryland, New Jersey, and Pennsylvania, and Canada comprised Ontario and Québec, while New York was in its own group. Responses were also grouped by production system (certified organic or conventional) for comparison.

INTERVIEWS. To gain greater depth of understanding of strawberry grower practices and needs, and to allow for growers to describe their experiences in their own words, we conducted a series of interviews in English with strawberry growers in the region. A sample for interviews was drawn from survey respondents who expressed interest in being interviewed. A total of 20 growers were identified using a maximum variability sampling approach (geography, sex, scale, experience, organic/conventional, and markets). A total of seven growers were interviewed; the other 13 did not respond to three separate requests.

Questions focused on growers' experiences in the following areas: marketing, desired cultivar attributes, tunnels and irrigation practices, and pest and disease challenges (Supplementary Material 2). Another set of questions focused on their perceived information needs and current sources of technical assistance. Interviewees were also asked about key lessons learned and how they

decide which management activities "pay for themselves" (i.e., generated sufficient revenue to justify the expense). Each interview was conducted via video chat using Microsoft Teams (version 1.5; Microsoft Corporation, Redmond, WA, USA) and lasted 30 to 60 min. The videos were not recorded; however, the interviewer took extensive notes during the interview. The data were analyzed to identify major themes using inductive coding. Interview notes were read, and recurring themes were given codes with descriptive titles.

Results

GROWER SURVEY. Strawberries accounted for less than 10% of farm revenue for the majority of strawberry growers in the mid-Atlantic region and southern New England, and for nearly half of New York farms (Table 1). For most growers in Ontario and Québec, strawberries accounted for 11% to 60% of farm revenue. In all regions surveyed, fewer than 7% of growers reported that strawberries accounted for more than 60% of farm revenues. Strawberry acreage is accordingly small, with a mean of 1.9 to 4.8 acres per farm for most regions, and 11.4 acres in Ontario and Québec. In all regions, most farms reported primarily growing June-bearing cultivars (>75% of production); however, day-neutral cultivars comprised the majority of production on 21% of farms in Ontario and Québec and 15% of farms in New York. A small percentage of farms in all regions reported growing a mix of both June-bearing and day-neutral cultivars, with >25% production of each.

Retail was the most common marketing strategy used by strawberry growers in all regions and overall (Table 2). Pick-your-own (PYO) and wholesale were also important. Community-supported agriculture markets were particularly important in northern and southern New England regions, and they are used by approximately one-quarter of respondents in each region. Nearly two-thirds of farms reported using more than one marketing strategy for their strawberries. Overall, 32 respondents reported producing certified organic strawberries, and 126 reported producing conventional strawberries. Only one operation reported producing both conventional and organic fruit, whereas all others produced one or the other.

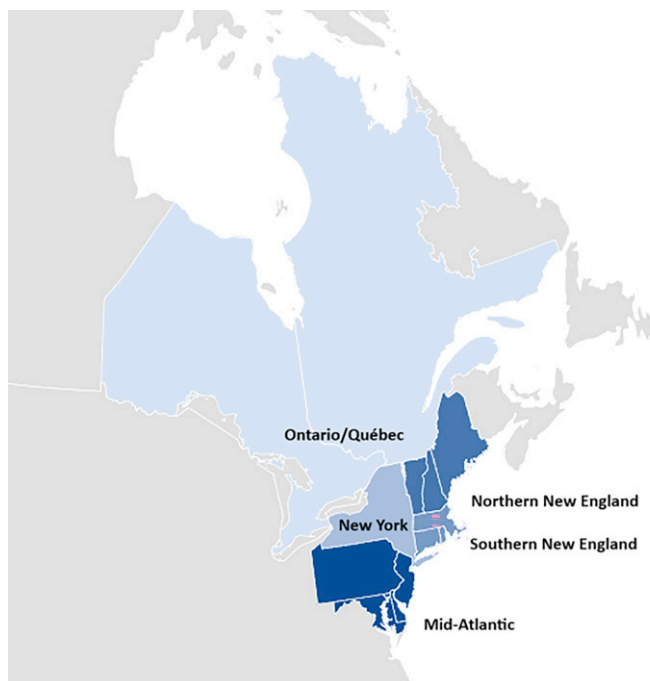


Fig. 1. The geographic regions represented by our 2020 survey of strawberry producers (Sideman et al. 2020).

Table 1. Percentage of farm revenue from strawberries, mean strawberry acreage, and types of strawberry grown of respondents from five regions within the survey area as reported in a survey of commercial growers in the northeastern US (mid-Atlantic region, New England, and New York) and Ontario and Québec, Canada, conducted between 1 Dec 2020 and 3 Feb 2021 (Sideman et al. 2020).

Region ⁱ	Percentage of revenue from strawberries ⁱⁱ			Strawberry acreage (Mean ± SD)	Types of strawberries grown ⁱⁱⁱ		
	<10%	11%–60%	>60%		June-bearing	Day-neutral	Mixture
Mid-Atlantic	57% ⁱⁱⁱ	32%	4%	4.8 ± 5.4	82%	7%	11%
Southern New England	64%	32%	4%	3.5 ± 3.8	92%	4%	4%
New York	47%	15%	3%	3.1 ± 4.6	74%	15%	12%
Northern New England	28%	35%	5%	1.9 ± 2.7	83%	5%	12%
Ontario and Québec	7%	86%	7%	11.4 ± 14.0	71%	21%	7%

ⁱ Regions included the mid-Atlantic (Delaware, Maryland, New Jersey, and Pennsylvania; n = 28), southern New England (Massachusetts, Connecticut, Rhode Island; n = 25), New York (n = 34), northern New England (Maine, Vermont, and New Hampshire; n = 57), and Ontario and Québec (n = 14).

ⁱⁱ The percentage of respondents from each region reporting revenue percentages in the three listed ranges.

ⁱⁱⁱ The percentage of respondents from each region reporting growing ≥75% June-bearing cultivars (June-bearing), ≥75% day-neutral cultivars (day-neutral), or growing >25% of both types (mixture).

The most common pest problems reported by the respondents were gray mold (*Botrytis*), weed competition, and leaf spot diseases [caused by various pathogens, including common leaf spot (*Mycosphaerella fragariae*), leaf scorch (*Diplocarpon earliana*), and Phomopsis leaf blight (*Dendrophoma obscurans*)]; all of these were mentioned by more than 70% of growers (Table 3). Birds, tarnished plant bug, and slugs were also among the top six pests, with each mentioned by 65% of growers. Some of the most important pests varied between regions. For example, although tarnished plant bug was the most prevalent pest according to Ontario and Québec growers, it was not among the top 10 for mid-Atlantic growers. In contrast, deer were more commonly reported by growers in the mid-Atlantic region than by those in other regions. Anthracnose fruit rot was prevalent in all regions, but it was only in the top six in the mid-Atlantic region, southern New England region, and Ontario and Québec. Key pests

were very similar between conventional and organic growers, with gray mold, weeds, birds, anthracnose, and slugs among the top five pest problems for both groups.

Most organic growers in the sample answered “none” to the number of pesticide applications made to their strawberry crop during the previous year (Table 4). Nearly one-third of organic growers reported applying one to three applications of general-use fungicides. A small percentage also reported that they applied restricted-use insecticides and fungicides. Because restricted-use (i.e., requiring pesticide applicator certification through a governmental agency) pesticides are not permitted in certified organic production, these respondents may have misunderstood the terminology used in our survey. “None” was also the most common response for conventional growers for all types of pesticides except herbicides (one to three applications was more common), with very small percentages of growers (2%–6%) applying more

than 10 applications of insecticides or fungicides.

Respondents were asked to report typical annual yields for harvested June-bearing and day-neutral crops. A wide range of yields, from less than 3000 lbs/acre to more than 15,000 lbs/acre annually, was reported (Table 5). Yields reported for June-bearing strawberries were frequently higher than those reported for day-neutral strawberries. The most common category for June-bearing yields was 5000 to 8000 lbs/acre, whereas the most common category for day-neutral was less than 3000 lbs/acre. The distribution of the reported yield responses from organic and conventional producers was similar; however, sample sizes were not large, and there was no clear evidence of yield differences based on the production system.

Using a list of all June-bearing and day-neutral cultivars available from nurseries commonly used by growers in the target region, respondents growing each type of cultivar were asked to indicate those that they consider

Table 2. Marketing strategies used for strawberries, as reported in a survey of commercial growers in the northeastern US (mid-Atlantic region, New England, and New York) and Ontario and Québec, Canada, conducted between 1 Dec 2020 and 3 Feb 2021 (Sideman et al. 2020).

Region ⁱⁱ	Marketing strategies used ⁱ				
	PYO	Retail	Wholesale	CSA	Other
Mid-Atlantic	54%	79%	54%	11%	0%
Southern New England	64%	88%	44%	24%	8%
New York	44%	91%	56%	9%	9%
Northern New England	47%	72%	46%	26%	4%
Ontario & Quebec	86%	79%	36%	7%	0%
Overall	54%	80%	48%	17%	4%

ⁱ The frequency of respondents from each region using each marketing strategy are shown: pick your own (PYO); community-supported agriculture (CSA); and jams, frozen, and other value-added products (other). Percentages do not sum to 100 because many respondents use more than one marketing strategy.

ⁱⁱ Regions included the mid-Atlantic (Delaware, Maryland, New Jersey, and Pennsylvania; n = 28), southern New England (Massachusetts, Connecticut, Rhode Island; n = 25); New York (n = 34), northern New England (Maine, Vermont, and New Hampshire; n = 57), and Ontario and Québec (n = 14).

Table 3. Percentage of strawberry growers experiencing the listed pests and the six most frequently mentioned pests by region in the years before 2020, as reported in a survey of commercial growers in the northeastern US (mid-Atlantic region, New England, and New York) and Ontario and Québec, Canada, conducted between 1 Dec 2020 and 3 Feb 2021 (Sideman et al. 2020).

Pest/disease ⁱ	Overall ⁱⁱ		Mid-Atlantic		Southern New England		New York		Northern New England		Ontario and Québec	
Gray mold (<i>Botrytis</i>)	79%	1	75%	3	76%	1.5	82%	2.5	79%	1	64%	2
Weed competition	78%	2	86%	1	76%	1.5	85%	1	70%	4	57%	4.5
Leaf spots	72%	3	71%	4.5	72%	3	76%	4	70%	4	43%	
Birds	65%	4.5	46%		52%	6.5	74%	5.5	75%	2	43%	
Tarnished plant bug (<i>Lygus lineolaris</i>)	65%	4.5	32%		64%	4	74%	5.5	70%	4	71%	1
Slugs (<i>Gastropoda: Pulmonata</i>)	65%	6	64%	6	60%	5	82%	2.5	54%	6	57%	4.5
Anthrachnose fruit rot	57%		79%	2	52%	6.5	62%		40%		57%	4.5
Deer (<i>Odocoileus virginianus</i>)	56%		71%	4.5	44%		56%		53%		36%	
Rodents	50%		43%		48%		65%		47%		36%	
Powdery mildew (<i>Podosphaera aphanis</i> var. <i>aphanis</i>)	44%		39%		36%		59%		35%		57%	4.5
Black root rot	34%		36%		28%		38%		28%		36%	
Spotted wing drosophila (<i>Drosophila suzukii</i>)	34%		25%		24%		47%		33%		36%	
Cyclamen mite (<i>Phytonemus pallidus</i>)	30%		14%		28%		41%		23%		50%	
White grubs (<i>Phyllophaga</i> spp.)	29%		7%		32%		35%		32%		36%	
Root weevils (<i>Otiobrychus</i> spp.)	22%		14%		40%		26%		16%		14%	
Nematodes (Nematoda)	18%		18%		8%		21%		14%		29%	
Strawberry rootworm (<i>Paria fragariae</i>)	15%		7%		4%		29%		16%		7%	

ⁱRegions included the mid-Atlantic (Delaware, Maryland, New Jersey, and Pennsylvania; n = 28), southern New England (Massachusetts, Connecticut, Rhode Island; n = 25); New York (n = 34); northern New England (Maine, Vermont, and New Hampshire; n = 57); and Ontario and Québec (n = 14). Data were self-reported in an online survey conducted between 1 Dec 2020 and 3 Feb 2021.

ⁱⁱFor each region and overall, the percentage of respondents reporting that each pest occurred in some or all years is presented as well as the overall rank for the most prevalent pests with a rank of 1 = most prevalent.

“tried and true” and those with which they were still experimenting. Among June-bearing cultivars, Jewel remains the most popular cultivar, with 50% of the 132 respondents from all regions considering it “tried and true.” ‘AC

Wendy’, ‘AC Valley Sunset’, ‘Cabot’, ‘Cavendish’, ‘Chandler’, ‘Earliglow’, and ‘Honeye’ were all considered “tried and true” by more than 20% of respondents. ‘Malwina’, ‘Rutgers Scarlet’, and ‘Flavorfest’ were each evaluated by

more than 20% of respondents, suggesting that growers are exploring their options for new cultivars. Two cultivars were particularly prominent in a subset of regions, for example, Annapolis in Canada and Allstar in southern New

Table 4. Percentage of organic (n = 25) and conventional (n = 109) strawberry growers reporting pesticide applications within each application quantity group during the previous year. Data were self-reported through a survey of commercial growers in the northeastern US (mid-Atlantic region, New England and New York) and Ontario and Québec, Canada, conducted between 1 Dec 2020 and 3 Feb 2021 (Sideman et al. 2020). Results reflect all regions and reflect applications made the previous year.

Production system	Number of applications	General use pesticides			Restricted use pesticides ⁱ		
		Insecticides	Fungicides	Herbicides	Insecticides	Fungicides	Herbicides
Organic	None	61%	54%	86%	79%	75%	82%
	1–3	21%	32%	0%	4%	7%	0%
	4–9	7%	0%	0%	0%	0%	0%
	>10	0%	0%	0%	0%	0%	0%
Conventional	None	44%	36%	42%	40%	44%	43%
	1–3	37%	26%	46%	32%	27%	35%
	4–9	17%	31%	7%	16%	12%	9%
	>10	2%	6%	0%	2%	4%	0%

ⁱRestricted-use pesticides include those requiring government-issued pesticide applicator certification for use. None are allowable products for use on certified organic farms.

Table 5. Distribution of yields of June-bearing and day-neutral strawberry plantings by production system across all regions. Data were self-reported in a survey of commercial growers in the northeastern US (mid-Atlantic region, New England, and New York) and Ontario and Québec, Canada, conducted between 1 Dec 2020 and 3 Feb 2021 (Sideman et al. 2020).

	June-bearing			Day-neutral		
	Overall ⁱ	Organic	Conventional	Overall	Organic	Conventional
<3000 lbs/acre	14.8%	3	10	37.9%	3	8
3000 to 5000 lbs/acre	25.0%	4	18	10.3%		3
5000 to 8000 lbs/acre	33.0%	9	20	20.7%	2	4
8000 to 10,000 lbs/acre	12.5%	2	9	6.9%		2
10,000 to 15,000 lbs/acre	11.4%		10	17.2%	1	4
>15,000 lbs/acre	3.4%	1	2	6.9%		2

ⁱ For each type of strawberry (June-bearing and day-neutral), percentages of growers overall and the number of organic and conventional producers reporting each yield range are given.

England. The choice of day-neutral cultivars was very consistent across all respondents/all regions. The primary “tried and true” cultivars were Albion (73% of respondents) and Seascape (60% of respondents). Meaningful percentages of growers regularly grew or were evaluating other cultivars, including Evie-2 (28%), Monterey (20%), and San Andreas (28%).

Organic growers reported a life span for June-bearing cultivars of 1 to 4 years, and conventional growers reported a life span of 1 to 8 years. The typical life span for a planting (mean \pm SD) was 1.54 ± 0.7 years for organic respondents, and it was 2.64 ± 1.1 years for conventional respondents. Some respondents noted that plantings in plasticulture were kept for only 1 to 2 years, whereas matted-row plantings were kept for considerably longer. We did not ask about the life span of plantings of day-neutral cultivars. However, because 35% of respondents indicated that they were keeping day-neutral plants over winter, it seems likely that day-neutral plantings are frequently kept for longer than a single fruiting season.

To better understand the diversity in production systems being used, we captured information regarding specific practices (Table 6). Although 29%

of those growing June-bearing strawberries only used overhead irrigation, many growers (50% for June-bearing and 85% for day-neutral) reported using drip irrigation. The use of plasticulture was popular for the production of both June-bearing (43% of growers) and day-neutral (75% of growers) strawberries. Compared with growers of June-bearing cultivars (4% and 3%, respectively), a higher percentage of day-neutral strawberry growers reported using high tunnels (13%) and low tunnels (20%).

We were particularly interested in winter and frost protection strategies used by growers in the target region. Traditionally, straw has been used for winter protection and overhead irrigation has been used for frost protection. Although a large percentage of respondents continue to use straw for winter protection (Fig. 2), at least 20% of respondents in each region are using row covers for this purpose. Similarly, although many growers reported using overhead irrigation for frost protection, more than 40% of growers in all regions reported using row covers for spring frost protection, even in the most northern regions.

Growers were asked to rank the resources and information they felt are most necessary for improving strawberry production and management (Table 7). For all respondents, the top-

ranked resource and information needs included pest/disease biology and identification, resistant cultivars, and action thresholds. Organic growers, but not conventional growers, ranked information specific to organic management as a top priority. Information about the performance of new June-bearing cultivars was ranked highly, whereas the same information about day-neutral cultivars was not. In terms of delivery methods, written fact sheets and comprehensive guides were ranked more highly than full-length webinars and 1- to 2-day tours of advanced strawberry operations.

INTERVIEWS. The interviewed farmers all identified as male; they lived in six states in the US (Pennsylvania, New Jersey, Vermont, Maine, New Hampshire, and Rhode Island) and one Canadian province (Ontario). They had between 6 and 34 years of strawberry growing experience and grew between 1.5 and 18 acres of strawberries in any given year. Two farms were certified organic and five farms were conventional operations.

The interviewed growers marketed their fruit through a variety of channels. Four offered PYO, three sold through both roadside stands and wholesale markets, one sold through farmers’ markets, and one sold through community-supported agriculture. One PYO operator stressed the importance of a

Table 6. Percentage of growers using specific practices for June-bearing and day-neutral cultivars across all regions. Data were self-reported in a survey of commercial growers in the northeastern US (mid-Atlantic region, New England, and New York) and Ontario and Québec, Canada, conducted between 1 Dec 2020 and 3 Feb 2021 (Sideman et al. 2020).

Type ⁱ	Irrigation methods used				Additional practices used					
	Overhead only	Drip only	Both	None	High tunnels	Low tunnels	Plasti culture	Hydroponic production	Biodegradable mulch	Over wintering
June-bearing	29%	50%	17%	4%	4%	3%	43%	ii		
Day-neutral	0%	85%	15%	0%	13%	20%	75%	13%	10%	35%

ⁱ Across all regions, respondents were asked about practices used when growing June-bearing (n = 126) and day-neutral (n = 34) cultivars.

ⁱⁱ When no information is provided, this question was not asked for this cultivar type.

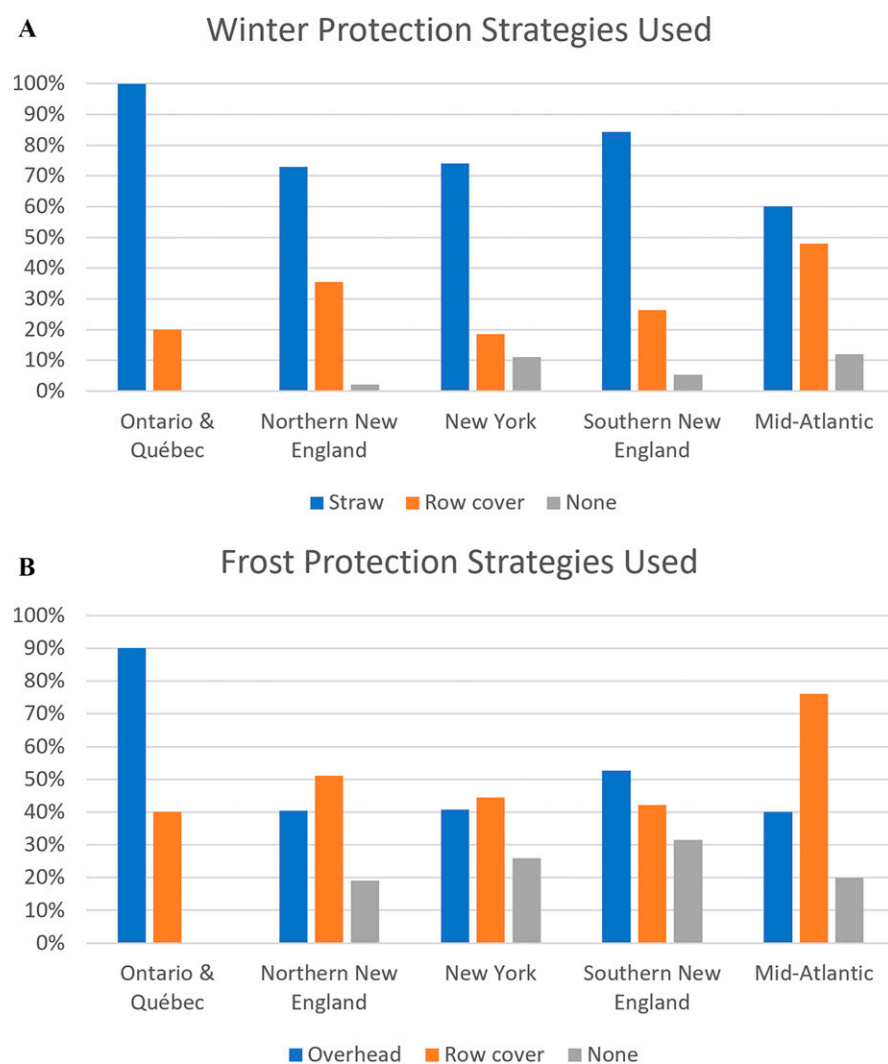


Fig. 2. The percentage of growers from each region who report using (A) straw, row cover, or neither for winter protection of strawberry and (B) overhead irrigation, row cover, or neither for spring frost protection of strawberry in our 2020 survey of strawberry producers (Sideman et al. 2020). Percentages sum to greater than 100 because some respondents reported using multiple methods. The regions are as follows: mid-Atlantic, Delaware, Maryland, New Jersey, and Pennsylvania (n = 28); southern New England, Massachusetts, Connecticut, Rhode Island (n = 25); New York (n = 34); northern New England, Maine, Vermont, and New Hampshire (n = 57); and Ontario and Québec (n = 14).

pleasant, accessible location and helpful staff to create a good experience, affirming that “customer service is the primary driver.” The farmer who sold through farmers’ markets emphasized that presentation on the stand is very important: “Unlike other fruits and vegetables we sell, the size of a strawberry is not a big marketer.” This farmer also noted the appeal of day-neutral strawberries, calling them a “money maker” by capturing a niche: “No one has grown day-neutral”; therefore, they are a big seller. One grower who sells wholesale lamented the increasing difficulty of selling to grocery stores. Local

independently owned stores offered the best markets to him because they providing the best fit for timing and quantity and had lower entry barriers. Because this type of store has become fewer in number, wholesale sales to these establishments have decreased.

When asked about desired cultivar attributes, the majority (three) of interviewed growers indicated flavor; however, size was also cited (two growers), and disease resistance, early yield, consistent yield, shelf life, and vigor were all cited by one grower each. The Ontario grower stressed the importance of regional adaptation.

Regarding flavor, one grower said, “people want taste out of their berries because we have been exposed to big berries in the grocery stores that have good shelf life but no taste.”

All growers produce June-bearing strawberries, and their views on day-neutral were mixed. One praised them for providing steady income throughout the season, whereas others found them difficult to grow (especially for one of the organic growers), lower-yielding, more disease-prone, and as attracters of insect pests such as spotted wing drosophila. One grower concluded that day-neutrals are “not worth it” for these reasons.

Every grower used drip irrigation. Four used overhead irrigation for frost protection. One previously used low tunnels but stopped because it was too labor-intensive, and they found the tunnels to be prone to overheating if not vented properly. None mentioned using high tunnels in the past or currently. Five growers reported using a matted-row production system and two reported plasticulture (with raised beds). For weed control, three used cover crops, three used herbicides, and two use mechanical cultivation.

Several pests and diseases were mentioned by the interviewed growers. Fungal diseases such as *Botrytis*, anthracnose, and *Fusarium* were mentioned. *Botrytis* was mentioned specifically in New Hampshire, Maine, and Rhode Island, and anthracnose was mentioned specifically in Pennsylvania. Common insect pests were identified as tarnished plant bug and spotted wing drosophila; one grower also mentioned aphid (*Aphididae*) damage. As discussed, day-neutral cultivars were viewed as being susceptible to, and even inviting of, disease. One farmer emphasized how important it was to obtain pest-free and pathogen-free plants because they can often be introduced on plant material.

When asked “how do you know what management activities pay for themselves?” the responses were very similar. Strawberries are a very high-value crop, and they can almost always sell what they produce; therefore, it is imperative to take measures to avoid crop loss. Frost and pest protection were noted as especially paramount in this regard.

The responses to research and extension needs were varied, with few repeating themes. Producers suggested investigating methods of improving

Table 7. Priority ranking of resources or information to improve strawberry management by organic and conventional producers. Data were self-reported in a survey of commercial growers in the northeastern US (mid-Atlantic region, New England, and New York) and Ontario and Quebec, Canada, conducted between 1 Dec 2020 and 3 Feb 2021 (Sideman et al. 2020).

What resources or information would help you to improve your management of STRAWBERRY in general?	Rank by organic producersⁱ	Rank by conventional producers
Scouting methods for specific pests	6	6
Pest and disease ID tools	3	2
Pest and disease ID services	10	7
Lists of pest-resistant cultivars	3	5
Information about pest/disease biology	1	3
Spray application methods	10	10
Herbicide use guidelines	15	13
Pest action thresholds (when to act)	6	4
Pesticide use guidelines	14	11
Cost/benefit analyses for different production systems	6	9
Guidelines for using row cover for winter or frost protection	6	8
Fertilization guidelines for plasticulture	12	12
Performance of new June-bearing cultivars	3	1
Performance of new day-neutral cultivars	13	14
Organic-specific information	1	15
What way(s) would you want to access this information?	Rankⁱⁱ	
Written fact sheets (accessible online)	1	
Comprehensive references such as the “Strawberry Production Guide for the Northeast”	2	
In-person meetings at research or farm sites	3	
Workshops and conferences	4	
Short instructional videos or “webinettes” (5–10 min maximum)	5	
An organized full-day or 2-day tour of advanced strawberry production operations	6	
Full-length webinars (typically 30 min to 1 h)	7	

ⁱ Resources were ranked (1 = high priority) according to the number of organic (n = 25) or conventional (n = 57) respondents who indicated that they would find each resource “helpful” or “very helpful.”

ⁱⁱ Delivery methods were ranked (1 = high priority) according to the number of respondents who indicated that they would find each “extremely useful” or “useful”; a single rank is presented because ranks were identical for organic and conventional producers.

ID = identification.

second-year yields, new and improved cultivars (especially for flavor), biocontrol education, and winter management methods. One urged research of the link between soil health and berry flavor.

Finally, interviewees were asked, “what do you wish you knew then that you know now?”. Several emphasized the importance of vigilance in insect control and advocated for scouting: “keep scouting and keep ahead of pests,” one said. One mentioned minimizing tillage and another reiterated the need to have “nice clean plants” to avoid bringing in pests on purchased transplants.

Discussion

Strawberries are an important crop for farmers in the northeastern US and Canada. Our survey and series of interviews explored the experiences and perceptions of strawberry growers in this region. We found that strawberries comprise a small percentage of overall revenue on farms, with

Ontario growers reporting the highest revenue share from the crop. Growers use diverse market channels, including direct markets, PYO, and wholesale, with most growers marketing their fruit through multiple channels. The vast majority of both survey and interview samples grow June-bearing strawberries, with smaller numbers growing day-neutral cultivars. Although the northeastern US is not a major strawberry-producing region in the country, our survey results highlighted their importance to retail operations early in the growing season.

Because of short northern growing conditions, the overall strawberry yield per acre reported by survey respondents was significantly lower than the national average of 52,900 lbs/acre (US Department of Agriculture, National Agriculture Statistics Service 2023a). More than half (58%) of growers reported June-bearing strawberry yields between 3000 and 8000 lbs/acre (Table 5). Our survey results aligned with agricultural census average yield

report in New England of 4620 lbs/acre in 2022 (US Department of Agriculture, National Agriculture Statistics Service 2023b), whereas the yield from Ontario was reported as nearly 7000 lbs/acre in 2022 (Ontario Ministry of Agriculture, Food and Rural Affairs 2023). In particular, day-neutral strawberry yields were remarkably low (Table 5), with the largest percentage of producers reporting a yield of less than 3000 lbs/acre. Low yields of day-neutral strawberries may be caused by pest and disease pressures that build over the long fruiting season, as interviewees mentioned. Additionally, more than half (56%) of day-neutral strawberry growers reported that strawberries comprise 10% or less of their total farm revenue; intensive management of a minor crop on diversified farms can be challenging. To advance strawberry production in the Northeast and improve yields, season extension, more efficacious integrated pest management (IPM) programs, and adapted cultivar

availability are three areas of improvement for the industry that could be explored in future extension programming.

As found by prior research (Black et al. 2002; Bornt et al. 1998; Hancock and Simpson 1995), the use of June-bearing cultivars and matted-row production remained very common in our sample, despite growing interest in plasticulture over the last two decades (Table 6) (Orde and Sideman 2023; Stevens et al. 2007). Plasticulture systems offer improved weed management, increased soil temperature, and earlier yields, but they require higher establishment investments and overall management (Orde and Sideman 2023). Although annual plasticulture production is popular in other parts of the country, many growers expressed an interest in keeping plasticulture strawberries for more than one season. Growers expressed a strong desire for more cultivar trialing as a research need, and previous experimentation has demonstrated significant differences in performance between June-bearing strawberry cultivars when grown in plasticulture (Weber 2021a). For example, some cultivars produce more runners than others, resulting in higher management costs in plasticulture systems because runners must be removed throughout the season. Because plug plants are often preferred for plasticulture, cultivar availability and seasonal availability of plugs also influence system performance (Weber 2021b). As new cultivars are released, continued trialing is necessary to determine whether they are suited for plasticulture in northern climates, as well as in organic production, protected culture, and other specialized systems. Plasticulture strawberry production may remain less popular than traditional matted-row systems in the Northeast until more clear recommendations for economical management and new cultivars are developed.

Weeds were presented as one of the most common pest problems in three of the five surveyed regions (Table 3) for surveyed growers, as found by prior research (Hernández-Martínez et al. 2023; Orde and Sideman 2023), perhaps because of the overall low adoption of plasticulture production. Fungal diseases including *Botrytis*, anthracnose, and *Fusarium*, and insects, such as tarnished plant bug and spotted wing drosophila, were

mentioned by both survey and interview respondents, echoing prior assessments (Lahiri et al. 2022; Orde and Sideman 2023; Poling 2008; Smith 2008). Specifically, pest management and disease management for day-neutral strawberries are often more challenging than those for June-bearing strawberries (Orde and Sideman 2023), which may provide a partial explanation for why June-bearing cultivars were more widely grown and reported to be higher-yielding by our survey participants and interviewees. In a changing climate, extreme weather events such as heavy rainfall, drought, and late frosts in the spring can stress plants and exacerbate strawberry disease issues; scientists anticipate an increase in the fruit crop disease incidence in the northeastern US because of climate change (Wolfe et al. 2017). Disease as a limiting factor to profitable strawberry production in the future highlights a need for IPM extension efforts and continuing focus on protected culture that mediates effects of climate variability. Additionally, a recent review of arthropod pests in strawberry by Lahiri et al. (2022) revealed a lack of comprehensive research of managing the strawberry pest complex, thus identifying a need for additional research in this area. Advances in organic pest management and biological control options are warranted to improve strawberry yields and economic viability in the northeastern US and Canada.

As found by previous studies (Anderson et al. 2019; Hernández-Martínez et al. 2023) our interviewees stated that strawberries are a very high-value crop, and efforts to protect from pests and preserve flavor are seen as worthwhile; however, not all practices have been found to be economically viable in the literature (Osatuke and Pritts 2021). In particular, intensive production practices, such as protected culture, plasticulture, and drip irrigation, were used more frequently for day-neutral than for June-bearing cultivars. The reason for this difference may be that day-neutral strawberries are more susceptible to pest and disease complexes that accumulate over a longer growing season, thus requiring more intensive management (Orde and Sideman 2023). Additionally, “off-season” strawberries are often sold at premium prices, warranting higher attention to quality through precision management. As observed during our interviews, not all

producers feel as though the timing of activities and workload of day-neutral cultivars fit well with their operations. A farm may need to specialize in or prioritize day-neutral strawberry production to be successful.

Surprisingly, some growers in our survey sample reported using no materials for the protection of overwintering strawberries. With the decreasing availability and increased cost of straw from cereal grains in some areas, producers may opt to use row cover or no cover at all. With increasingly warmer winter temperatures, producers in the southern regions of our surveyed areas may opt to save labor and materials costs by foregoing winter protection if yield is not impacted. In particular, more producers in the mid-Atlantic region reported using no winter protection, and this trend has been seen as emerging in other regions as well (McDermott LG, personal observation).

Growers in both samples were interested in research and outreach of pest control, including biology, identification, and economic thresholds in the survey sample and biocontrols in the interview sample. The survey sample preferred written material such as handouts and production guides. It is important to note that our survey was distributed during the COVID-19 pandemic, when most extension outreach was conducted virtually. Webinars and videos were ranked among the least preferred outreach methods. In other surveys, however, growers vary widely in their outreach preferences, and a mixture of in-person, virtual, electronic, and print outreach is needed to meet the needs of diverse audiences (Hodgdon EA and McDermott LG, personal observation; Witzling et al. 2023).

Our results suggest a few key implications. First, our interviews suggest a need for research of improved IPM strategies, particularly for organic growers. Second, research, or at least increased communication, of weed control and disease, as well as cultivar trialing, is also needed. Third, outreach would be most effective if presented in accessible written handouts and included in a comprehensive growers’ guide that could be available in print and online. Our survey and interview findings may serve as a needs assessment for future research and extension efforts in the northeastern US and adjacent Canada.

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